Response to Referee #2

General Comments: This study investigated the black carbon "dome effect" and its key influencing factors, namely the vertical distribution and aging processes of BC, and the underlying land surface. The "dome effect" can play an important role in haze evolutions, which makes this study an interesting topic. Also, the manuscript is well organized and clearly presented, and is worth publishing. However, several concerns need to be addressed before the final publication.

Response: We would like to thank the referees for their time and useful comments towards the improvement of our manuscript. We have made careful considerations and now reply to the comments one by one.

Specific Comments: 1. One major concern of this study is the lacking of information on actual scenarios. While low-level BC can enhance PBL height while upper-level would suppress that, what is the approximate threshold of low-level BC to upper-level BC concentration ratios, at which these two effects can offset each other? Is this threshold easily reached during haze events? That is, how often and how universal is the "dome effect" present? In actual scenarios, the BC are more likely to be composed of both a low-level freshly emitted peak, and an upper-level transported peak. Their different ratios may lead to different overall effect. Since observation on vertical BC profile is scarce, a relatively long-term simulation covering a larger domain (e.g., northern and eastern China) with actual configurations like the one shown in Fig. 1 might be helpful, or at least this issue should be discussed in more detail.

Response: Thanks for the suggestion. This work is a complementary study to our previous work, Ding et al. (2016), which is based on 3D simulations with actual scenarios. Of course, 3-D modelling for a larger domain and for a longer period will be helpful for quantifying the overall impact of the "dome effect" of BC. However, comprehensive 3D modelling with real scenarios sometimes is difficult to identify the key factors because of its complexity. This is the reason why only 1-D modelling with ideal scenarios was considered in this study. As mentioned, BC vertical distribution can be quite heterogeneous due to synoptic weather conditions or long-distance transport. That is to say, the height of the upper-level transported peak and the ratio of the upper- to lower-level BC concentration can vary a lot (Li et al., 2015;Allen and Landuyt, 2014;Trompetter et al., 2013), and the meteorological conditions in different regions may also lead to varied threshold concentrations. Therefore, it may be difficult to determine a universally applied threshold in different region. Specifically, in Beijing, if the upper-level (about 1000m) and lower-level BC are 5 and 20 μg m^{-3} respectively (Li et al., 2015), which represents the common situation during heavy polluted days, dome effect will occur with a ratio of upper-level to lower-level BC concentration being about 0.25. Thus in actual scenarios, the threshold of dome effect can be easily reached. We also analysed the result of regional modelling in Ding et al. (2016) for the whole month of December in 2013, and found that dome effect enhanced the atmospheric stability (PBL height decreases over 10%) in 66%, 73%, 69% and 66% of days for four different cities: ZZ (34.73° N, 113.61° E), SJZ (38.04° N, 114.71° E), SH (31.21° N, 121.45° E), NJ (32.08° N, 118.77° E). Furthermore, the frequency increased to over 90% during pollution episode. We also performed our simulations over these cities in northern and eastern China during several winter haze episodes, and we found the same "dome effect" exist in these cities with different PBL decreasing. Hence, the occurrence of "dome effect" can be seen as quite universal and frequent in northern and eastern China when heavy polluted events take place. Relevant descriptions will be added in Section 3.1 in the revised manuscript.

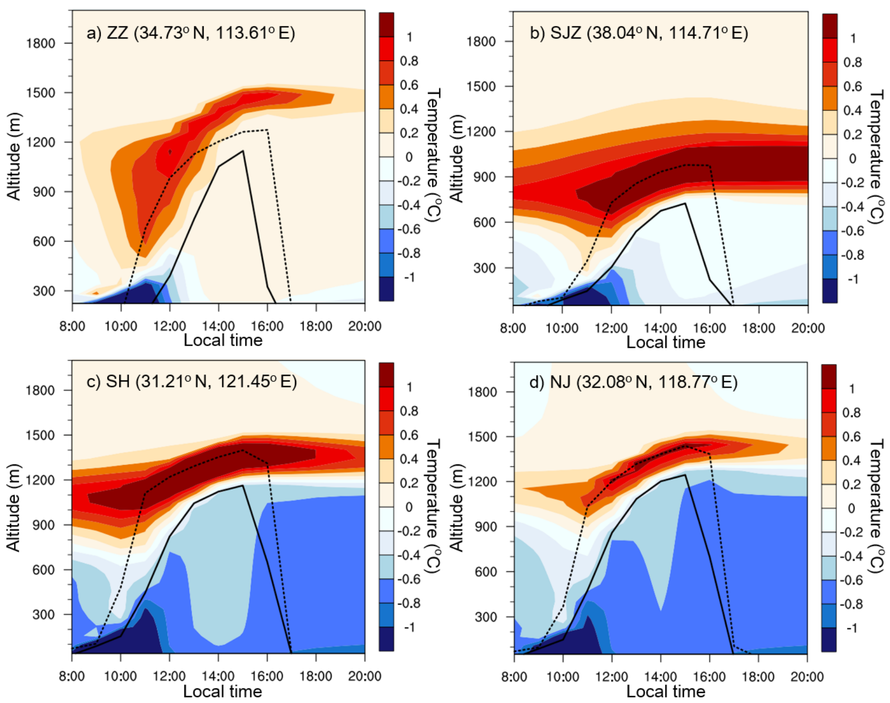

Fig. R1 Diurnal variations of the air temperature change caused by aerosols during haze episode in Zhengzhou (ZZ), Shijiazhuang (SJZ), Shanghai (SH) and Nanjing (NJ), and of PBL height for runs with (solid line) and without (dash line) ARI.

2. Although the simulation results are well explained, the conclusion about chimneys and domestic stoves seems somewhat abrupt. What is the typical height of chimneys? Can that compare to the height of the inversion layer? It was more confusing on the conclusions about domestic stoves at rural areas. In the context of this manuscript, the *depression of PBL at rural areas should be caused mainly by the long-range transported upper-level BC, not the local emitted ones. On the contrary, the freshly emitted BC would serve as the low-level BC and tend to enhance the PBL. Thus the fact that rural areas are more sensitive to "dome effect" would lead to the conclusion that reducing long-range transported upper-level BC is more important. The casual relationship should be better described.*

<u>Response</u>: Thanks for raising these points. We agree that the relationship of these discussion should be better described. The typical height of chimneys and stack for power plants are higher than 200 m in China (Hao et al., 2007;Zhou et al., 2003). Further, the emissions of these coal-fired power factories tend to be much warmer than the ambient air and thus will rise and expand to cool down, after which it may possess a height of around 300 m (Ito et al., 2006;Zhou et al., 2003). In a modern coal-fired power plant, the average particle size in the stack gas is often the scale of sub-micrometre to approximately a few micrometres. Hence, the effect of gravitational sedimentation is expected to be quite small. During winter time, nocturnal residual layer could be as low as 200 m, leading to emissions from stacks to be lifted above the inversion layer. Our key point is that the elevated sources are easily to be long-range transported, so the BC reduction from these sources should be paid more attention if the dome effect is considered. As for domestic stoves at rural areas, although this kind of emission sources mainly locate on the ground, daytime convective motions play an important role in lifting near-surface pollutants to upper-level PBL (Wakimoto and L. McElroy, 1986;Gimson, 1997;Li, 2005), where the dome effect of BC will also play important role in enhancing air pollution. Anyway, we will re-organize these sentences to better express our conclusion or suggestions.

3. Page 2 Line 1: "developed regions like...": change into "the more developed regions like..."

<u>Response</u>: Accepted.

4. Page 2 Line 6: is the "680 ug/m3" daily average? Later the hourly maximum of ~900 ug/m3 is mentioned, so here need some clarification.

<u>Response</u>: The "680 ug/m^3" is the hourly maximum $PM_{2.5}$ concentration for haze pollution in January, 2013 (Wang et al., 2013) , while "~900 ug/m3" is the maximum hourly concentration in December, 2013 (Zheng et al., 2015). These data are from different pollution episode. More description is given in the revised version.

5. Page 2 Line 17-L18: consider change the expression of "concentration of BC... far more than..."; "more concentration" seems strange.

<u>Response</u>: Accepted. We will change it to "concentration of BC… higher than…" in the revised manuscript.

Reference:

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